

PART III

COMPARING ALTERNATIVES

Chapter 9

COMPARATIVE COSTS

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Discussions of the importance of continuing and enhancing existing transit service, proposals for development of new systems, and plans for capital investment in existing transit systems are supported by any number of concerns that hold out promise for solution to many urban ills. Public transit has been put forth as part of the solution to:

- Handicapped persons' mobility.
- Economically disadvantaged persons' mobility.
- Cleanup of the environment.
- Urban traffic problems.
- Travel-time savings.
- Shaping urban development.
- Saving energy.

Notwithstanding each of these valid considerations, in the final analysis, urban agencies charged with providing

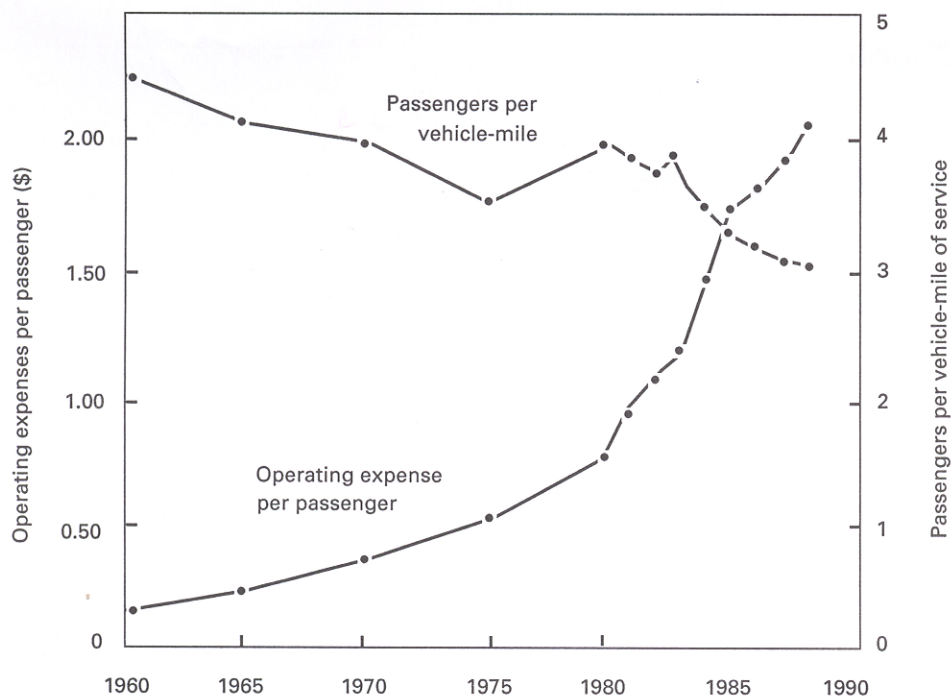


Figure 9-1 Relationship of expense per passenger and passengers per vehicle-mi, U.S. transit systems, 1960-1988. [Source: American Public Transit Association, Transit Fact Book, 1989 ed. (Washington, D.C.: American Public Transit Association, 1989).]

inflation and price increases for labor and materials, the growth of automobile ownership and its consequent impact on the location and distribution of urban activities have been a major factor in lower system effectiveness. Similar to many other collective goods and services, urban sprawl has had a deleterious impact on mass transportation.

In response to the economic resource allocation problem, several sound approaches have been developed to analyze comparative costs of alternative solutions for three basic purposes:

1. Urban areas with fully developed multimodal transit systems coincidentally are almost universally faced with financial problems, which have caused the dilemma of maintaining or improving existing operations while trying to control deficits, leading to a search for methods of productivity improvement.
2. Considerations for short-term service expansions require comparative operating cost analysis to ensure the most cost-effective method of expansion.
3. Longer-range planning for capital improvements to existing systems and/or for installation of completely new systems requires detailed estimates of comparative capital and operating expenses so that the most cost-effective solution is assured.

These purposes are driven by the resource allocation question addressed earlier. This question is at issue at all levels of government—federal down to local. The allocation problem has separated itself into the two basic cost areas: capital and operating costs. Historically, capital expenses have involved the replacement of rolling stock and renovation of fixed facilities with substantial assistance from federal grants (at least since 1964). Financial requirements for capital assistance, however, have constituted a relatively minor portion of the total financial problem, while operating deficits are approaching \$10 billion per year. Furthermore, the trend of operating losses indicates an aggravation of this disparity in the future. Figure 9-2 illustrates this

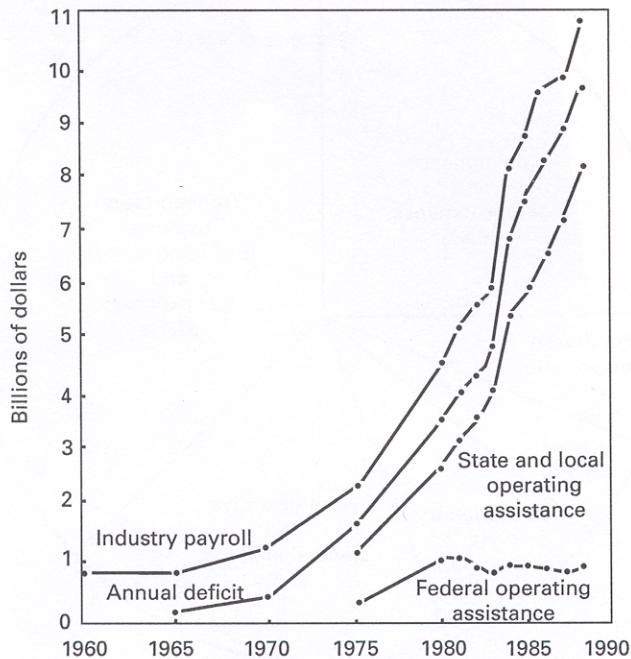


Figure 9-2 Trend of operating deficit—U.S. transit industry.

trend and shows further the widening of the gap between federal operating assistance under the Urban Mass Transportation Act and the industry deficit. The gap between federal assistance and operating deficits has been largely filled by increased state and local funds. The figure also demonstrates the labor-intensive nature of public transit wherein the deficit curve is almost in parallel with the industry payroll. This chapter concerns itself with an exploration of these costs and the derivation of methods of estimating their magnitude so that comparative costs can be prepared for use in situations in the three alternative solutions enumerated. The chapter is organized into a discussion of operating costs—their component composition, their variance by mode, and methods of calculation—and then capital costs, which are similarly addressed.

OPERATING COSTS

Figure 9-3 provides an overview of the composition of operating expenses for the U.S. transit industry. These major categories include transportation expense, which is

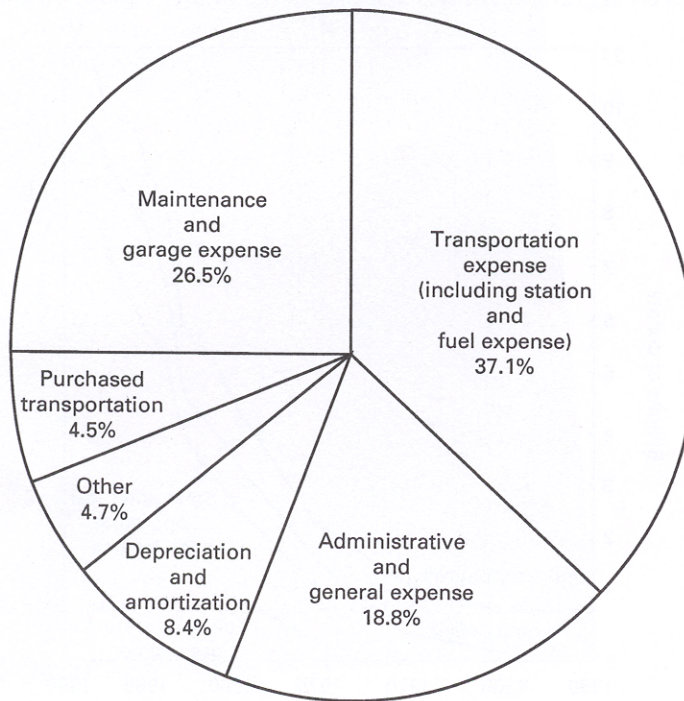


Figure 9-3 Distribution of nationwide transit operating expenses. [Source: American Public Transit Association, Transit Fact Book, 1989 ed. (Washington, D.C.: American Public Transit Association, August 1989).]

basically the cost of providing the service in the form of drivers, supervisory personnel, and fuel and constitutes over one-third of the total costs (37.1%), and maintenance and garage expenses, which involve primarily repairs to rolling stock, including the labor associated with that function—this category constitutes 26.5% on the average. The next largest category involves administrative and general expenses, including personnel costs, insurance, and safety, which constitute 18.8% of expenses. The balance of all other

categories is 17.6%. In total, labor-related expenses in the form of wages, salaries and fringe benefits vary by system, but generally constitute 60 to 75% of total cost.

Operating expenses vary significantly by mode of operation and within modes for different operating systems. Table 9-1 compares costs for existing transit modes in 1989: heavy rail (rail rapid transit), commuter rail, light rail/streetcar, and bus. For comparative purposes, it is useful to examine these statistics on unit bases in terms of the cost of providing the service per unit of service provided (number of vehicle-mi operated annually) and per passenger carried.

Heavy rail services (rail rapid transit) display an average cost of \$6.53/vehicle-mi with a range from \$3.66 in Atlanta to \$8.97 in Boston. This variance is partially explained by the fact that the top operator wage rate in Atlanta is \$12.71/h, while Boston's is \$17.57. Furthermore, Atlanta's system is quite new.

Commuter rail services involve even wider variations, ranging from \$5.06/vehicle-mi for Caltrans service to San Diego (which is operated under contract) to \$12.39 for SEPTA services in Philadelphia. The average for this mode is \$8.06 per vehicle-mi.

The greatest variance in unit cost occurs in light rail systems with a range from \$3.71/vehicle-mi on the San Diego Trolley to \$17.87 in Boston, with an average value of \$9.11. Once again, this difference is partially explained by wage rates, with San Diego's top operator rate at \$13.65/h compared to Boston's rate of \$17.76. More of the variance is explained by the fact that San Diego is a new system specifically designed for low-cost operation and includes an honor fare collection system that reduces labor costs considerably.

Bus costs average \$4.59/vehicle mi, with a range from \$3.16 in Portland to \$8.82 in New York. In this case, the variance relates to wage rates but is more influenced by speed (for example, fewer mi/h with operators paid by the h). The average speed of Portland's system is 14 mi/h, while New York's is only 8.3 mi/h.

It is important to note in reviewing these expenses that there are differences that, in some cases, result from the methods of allocating expenses where a system operates more than one mode of service.

Examination of operating expenses per passenger carried indicates similar wide swings in unit costs, although the averages among modes are more closely aligned. Heavy rail, light rail, and bus are clustered at \$1.98, \$1.46, and \$1.37, respectively; commuter rail stands out at \$5.47, largely because this mode generally serves much longer trips. For example, if the same statistics were examined on a cost per passenger-mi of travel basis, the commuter rail average would be approximately one-half the bus average (\$0.24/passenger-mi for commuter rail and \$0.46 for bus).

TABLE 9-1
Representative Operating Costs Existing Transit Modes

City/System	Operating Expenses/ Vehicle Miles				(\$)/Operating Expenses /Passenger (\$)				Bus
	Heavy Rail	Commuter Rail	Light Rail	Bus Rail	Heavy Rail	Commuter Rail	Light Rail	Bus	
New York/MTA		7.23	8.58	—	8.82	1.54	5.83	—	1.30
Chicago/RTA	3.88	8.49	—	5.08	1.24	3.73	—	0.89	
Philadelphia/SEPTA	7.18		12.39	8.88	4.58	1.20	5.61	1.05	0.92
Washington/Wmata	7.09	—	—	5.51	1.37	—	—	—	1.61
Boston/MBTA		8.97	6.91	17.87	5.58	1.24	4.54	1.02	1.36
San Francisco/Muni, BART/Caltrain		5.15	9.91	12.19	6.67	2.74	4.38	1.25	1.06
Baltimore/MTA		6.65	N.A.	—	4.11	2.23	N.A.	—	0.96
Atlanta/MARTA		3.66	—	—	3.29	0.75	—	—	1.19
New Jersey/NJT		—	7.24	5.24	3.42	—	5.62	0.88	1.96
Miami/Metro-Dade	7.27	—	—	4.32	3.60	—	—	—	1.74

Portland/Ti-Met	—	—	5.53	3.16	—	—	1.40	1.37
Sacramento/SRTD	—	8.07	3.75	—	—	2.13	2.11	
Average	6.53	8.06	9.11	4.59	1.98	5.47	1.46	1.37
Range as a percentage of average	81%	91%	155%	123%	158%	82%	109%	91%

Source: 1989 Transit Operating and Financial Statistics—American Public Transit Association.

250

COMPARATIVE COSTS 251

these reasons, methods of calculating operating expense for these modes have been developed utilizing multivariable cost allocation models that are calibrated for the expense conditions of the existing or proposed transit system being analyzed. A second cost allocation technique is utilization of models that have been developed to estimate the incremental cost (or savings) of changes in existing service by isolating fixed and variable costs. Another operating expense estimation technique (more appropriate to situations where no existing system is in place) is to "buildup" expenses by estimating numbers of personnel and materials for each functional department.

These techniques have been developed in response to the common questions of managers and planners of transit systems:

1. What is the relative financial performance of each of the routes in my system (that is, route revenue versus route cost)? This can be answered with fully allocated cost models.
2. What would the cost be if I modified a route (that is, more or less than current cost)?—this can be answered with incremental cost models.
3. What would it cost to institute a brand new service (for example, light rail)? This can be answered with a cost buildup model.

where C_t = total cost of transit services (input) R = transit resources provided (output) n = number of resources provided

Normally, the cost of providing transit services is presented in a standard list of expense accounts. The cost of each expense account can be denoted C_i , which is the cost of expense account i . The total cost of operations, C_t , for all m expense accounts can be mathematically defined as shown in Eq. (9-2):

252 Comparing Alternative

$$C_t = \sum_{I=1}^m C_i \quad (9.2)$$

where C_i = cost of expense account I
 C_t = Total cost
 m = number of expense accounts

Equation (9-2) represents the input side of transit operations in terms of total cost and the individual cost components. From Eqs. (9-1) and (9-2), it is clear that the input-output relationship for costs and resources can be stated for individual expense accounts as shown in Eq. (9-3):

$$\sum_{j=1}^n P_{ij} = 1 \quad (9-4)$$

where P_{ij} = proportion of cost for expense account i allocated to resource j

Based on Eq. (9-4), the cost for each expense account can be allocated to each resource as shown in Eq. (9-5):

$$C_{ij} = C_i P_{ij} \quad (9-5)$$

where C_{ij} = cost allocated to resource j for expense account i

By summing all the expense account amounts by resource, the total cost can be stratified by resource as shown in Eq. (9-6):

$$C_j = \sum_{i=1}^m C_{ij} \quad (9-6)$$

where C_j = cost allocated to resource j

COMPARATIVE COSTS 253

Thus, the sum of costs allocated to each resource is a rearrangement of cost by resources provided rather than expense accounts and will equal the total system cost, as shown in Eq. (9-7):

where U_j = unit cost for resource j

The multivariable cost allocation model can be defined as shown in Eq. (9-9):

$$C_t = U_1R_1 + U_2R_2 + U_3R_3 + \dots + U_nR_n \quad (9-9)$$

Given a set of resource levels for a particular transit route or line, the unit cost can be applied to compute the cost of the particular transit services comprising the transit system. Thus, the cost allocation model is quantified from overall system statistics but is applied on individual components that comprise the system.

OPERATING COST MODEL EXAMPLES

Having defined the theoretical framework of the cost allocation model, let us apply this approach to the transit operators in the Chicago metropolitan area. (Chicago is used as an example because a number of different modes are operated in that area.) A total of five resources were identified as influencing transit operating costs of any mode to be examined:

- ° Vehicle (car)-miles.
- ° Vehicle-hou
- Track-miles.
- Peak vehicles (cars).
- ° System revenue.

Closer scrutiny of the operations of rail and bus carriers suggested that vehicle-mi, peak vehicles, and system revenue should be included in the development of both rail

rather than vehicle-h. In addition, rail carriers compile operating statistics by vehicle-mi rather than vehicle-h.

Commuter Railroad Cost Models

For each of the eight railroads operating in the Chicago area, the carrier's expenses were allocated to one of four resources or variables: car-mi, peak car needs, track-mi, and system revenue.

Car-miles. A number of costs are related directly to miles of operation. Expenses such as fuel and maintenance of cars and engines are a direct function of the number of miles operated. Train engineer's wages are also assigned to the category of car-miles.

Peak car needs. The cost resulting from providing storage, operation, and maintenance facilities for cars is a function of the number of cars required to operate the service, rather than the number of miles of service provided. Another significant cost item that varies with the number of peak cars is depreciation. Additionally, salaries of general office personnel and train crew wages are assigned to the category of peak car needs.

Track-miles. Several classes of operating expenses in rail service are a function of the number of miles of track. Such costs include, for example, road property depreciation and maintenance of office buildings. The cost of these items is a function of the number of units, rather than volume of service operated.

System revenue. Traffic and certain insurance expenses are assigned to the system revenue category, as they are a function of passenger volume, which is proportional to system revenue.

The classification of each operating expense item into one of the four allocation resources is reflected in Table 9-2. This table presents all the operating expense accounts to which charges were made. To permit fair and unbiased comparisons between carriers, the percentage allocations were the same for all commuter railroads.

Table 9-2
Allocation of Expense Accounts— Commuter Railroad

Expense	Basis for Allocation		Track-Milesa	Sytaem Revenue
	Car-Milesa	Peak Car Needs		
Maintenance orway and structures				
Superintendence			100%	
Roadway maintenance		50%	50%	
Ties and rails	100%			
Ballast & other track material	50%		50%	
Track laying & surfacing	50%		50%	
Fences, snowsheds, & signs		100%		
Stations, office, & roadway buildings		100%		
Water & fuel stations		100%		
Shops & engine houses		100%		
Communication systems	100%			
Signals & interlockings		100%		
Power plants & transmission		100%		
Road property—depreciation		100%		
Roadway machines	100%			
Dismantling road machinery		100%		
Small tools & supplies		100%		
Removing snow, ice, & sand		100%		
Public improvements—maintenance		100%		
Insurance & injuries to persons		50%	50%	
Stationery & printing		50%	50%	
Employees' health & welfare benefits	50%		50%	
Maintaining joint facilities_net		50%	50%	
Other expenses	50%	50%		
Maintenance of equipment				
Superintendence		100%		
Shop & power-plant machinery		100%		
Diesel locomotives—repairs	100%			
Passenger train cars—repairs	100%			
Other equipment—repairs		100%		
Equipment depreciation		100%		
Insurance & injuries to persons		100%		
Stationery & printing	50%	50%		
Other expenses	50%	50%		

Transportation			
Superintendence	100%		
Dispatching trains	100%		
Station employees, supplies, & expenses			100%
Yard employees, supplies, & expenses	100%		
Train engineers			
Train fuel & servicing	100%		
Locomotives	100%		
Train crew			
Train supplies and Expenses	50%	50%	
Signal & interlocking Operation	100%		
Crossing protection		100%	
Drawbridge operation	100%		
Communication system	100%		
Employees' health & welfare benefits	50%	50%	
Stationery and printing			100%
Operating joint facilities _net	50%	50%	
Insurance a injuries to persons			100%
Damage to property		100%	
Damage to livestock on ROW		100%	
Other expenses	100%		
General and miscellaneous			
Salaries & expenses of general officers	100%		
Salaries & expenses of clerks & attendants	100%		
General office supplies & expenses	100%		
Law expenses and insurance			100%

Interest on equip.obligations 100%

aMetric conversion: 1 mi = 1.6 km.

bAllocated on the basis of total employee compensation by major employment categories (e.g., maintenance of way and structures, traffic, transportation, etc.).

Source: Adapted from Walter Cherwony and Brian McCollom, "Development of Multi-Modal Cost Allocation Models," in *The Proceedings of the Fourth Intersociety Conference on Transportation* (Los Angeles: The American Society of Mechanical Engineers, July 1976), pp. 1-9.

For example, the cost allocation model development for the Chicago and North Western Transportation Company resulted in the apportionment of 39.14% of aggregate cost on the basis of car-mi, 46.11% on the basis of peak car needs, 5.23% allocated on a track-mi basis, and the remaining 9.52% as a function of system revenue. Table 9-3 reflects these apportionments and also indicates the relative weight of each resource variable on a unit cost basis. While actual dollar amounts in these examples are for 1976, the technique and relative results remain valid.

256

TABLE 9-3
Operating-Co st-Allocation-Model Development—
Chicago and North Western Transportation Company

Basis of Allocation	Total Units	Total Cost	% of Allocated	Unit cost
Car-miles ^a	11,104,691	\$ 9,272,264	39.14	\$0.83/car-mi
Park car needs	256	10,923,612	46.11	\$42,670.36/peak car
Track-miles ^a	358.9	1,239,684	5.23	\$3454.12/track-mi
System revenue	\$24,278,000	2,254 440	9.52	\$0.09/\$1 of system rev
Total		\$23,690,000	100.00	

aMetric conversion: 1 mi = 1.6 km.

Source: Walter Chenwony and Brian McCollom, "Development of Multi-Modal Cost Allocation Models," in *The Proceedings of the Fourth Intersociety Conference on Transportation Los Angeles: The American Society of Mechanical Engineers*, July 1976), pp. 1-9.

For the Chicago and North Western Transportation Company, the four-variable analysis resulted in the following formula of cost allocation:

$$C = 0.83M + 42,670.36V + 3454.12L + 0.09R \quad (9-10)$$

where C = annual cost of system operation

M = annual car-miles of service

discussion of this mode is not included here. For completeness, however, the cost model is shown in Eq. (9-11):

$$C = 0.64M + 27,152.17V + 34,119.80L + 0.36R \text{ (9-11)}$$

Bus Service Cost Models

In a similar fashion to that used for the region's rail carriers, expense accounts for the 10 major bus operators were allocated to one of four resources or variables: vehicles, vehicle-mi, peak vehicle needs, and system revenue.

TABLE 9-4
Operating-Cost-Allocation-Model Results —Commuter Railroads

Unit Cost Factors					
Carrier	Power Source	Car-Miles ^a (\$/car-mi)	Park Car Needs (\$/peak car)	Track-Miles ^a (\$/track-mi)	System Reveue (\$/\$)
BurlingtonNorthern	Diesel	1.25	46,265	6066	0.08
Chicago and North Western	Diesel	0.83	42,670	3454	0.09
Chicago,Milwaukee, St.Paul, & Pacific	Diesel	1.19	67,522	3162	0.10
Chicago, Rock Island, And pacific	Diesel	1.29	28,409	4957	0.17
Norfolk and Western	Diesel	2.31	13,383	235	0.0003
Penn Central	Diesel	1.23	39.079	839	0.02

COMPARATIVE COSTS 259

Vehicle-hours. Operating employees wages represent by far the largest single element of cost in most bus transit properties. Employees engaged in operating vehicles are paid on an hourly basis; hence, the allocation of wage expense is most properly made on the basis of hours of service on the system. Similarly, supervision of transportation operations is directly related to the number of hours of service provided, and this item is also properly allocated to the vehicle-h category.

Vehicle-miles. Many costs are related directly to the miles a bus system operates. Expenses such as fuel, tires, and equipment maintenance are a direct function of miles operated. Material expenses for vehicle bodies, brakes, engines, chassis, and transmissions are also a function of exposure in terms of miles of service. Consequently,

System revenue. Operating costs resulting from injuries and damages are logically assigned to the system revenue category. Traffic promotion, station expenses, and federal income and other taxes are also assigned to this category because they relate primarily to system revenue. The classification of each operating expense into one of four allocation variables is presented in Table 9-5. This table aggregates all the operating expense accounts to which charges were made. To facilitate bus operator comparisons, the percentage allocations were the same for all bus systems.

As an example, the development of the cost allocation model for the Chicago Transit Authority bus operations resulted in the apportionment of 14.69% of aggregate costs on the basis of vehicle-mi, 54.62% on the basis of vehicle-h, 25.60% allocated on peak vehicle needs basis, and the remaining 5.09% as a function of system revenue (Table 9- 6). For the Chicago Transit Authority, the resultant bus operations cost allocation formula follows:

$$C = 11.13H + 0.28M + 20,059.22V + 0.06R \quad (9-12)$$

where C = annual cost of system operation
H = annual vehicle-hours of service
M = annual vehicle-miles of service
V = Peak vehicle needs
R = annual system revenue

TABLE 9.5
Allocation of Expense Accounts Bus Operations

Bus drivers	100%		
Fuel		100%	
Lubricants		100%	
Service equipment operation	100%		
Other transportation expenses			100%
General and miscellaneous expenses			
Salaries &: expenses of general officers		100%	
Salaries & expenses of general office clerks		100%	
General office rent		100%	
General office supplies &: expenses		100%	
Traffic promotion			100%
Other general expenses		100%	
Insurance			
Fire, theft, collision			
Public liability and property damage			100%
Workmen's compensation			
Taxes			
General state and local		100%	
State franchise tax on capital stock			100%
Licenses		100%	
Other local		100%	
U.S. motor fuel and oil			
Payrollb			
Depreciation			
Building and fixtures		100%	
Motor buses		100%	
Service equipment		100%	
Garage equipment		100%	
Office furniture and equipment		100%	
Miscellaneous equipment		100%	

aMetric conversion 1 mi = 1.6 km.

bAllocated on the basis of total employee compensation by major employment categories (e.g. maintenance, transportation, general office, etc.).

Source: Adapted from Walter Cherwony and Brian McCollom, "Development of Multi-Modal Cost Allocation Models, in *The Proceedings of the Fourth Intersociety Conference on Transportation* (Los Angeles: The American Society of Mechanical Engineers, July 19 76), pp. 1-9.

Vehicle-miles ^a	90,701,804	\$ 25,431,448	14.69	\$0.28/vehicle-mi
Vehicle-hours	8,500,071	94,527,897	54.26	\$11.13/vehicle-h
Peak vehicles	2210	44,330,511	25.60	\$20,059.22/peak
System revenue	\$138,832,579	8,806,063	<u>5.09</u>	\$0.06/\$1 of system rev.
Total	\$173,140,919	100.00		

^aMetric conversion: 1 mi = 1.6 km.

Source: Adapted from Walter Cherwony and Brian McCollom, "Development of Multi-Modal Cost Allocation Models," in *The Proceedings of the Fourth Intersociety Conference on Transportation* (Los Angeles: The American Society of Mechanical Engineers, July 1976), pp. 1-9.

The results of the development of the cost allocation model for the 10 major bus operators in the Chicago metropolitan area are presented in Table 9-7.

INCREMENTAL COST OF SERVICE MODEL

This approach uses the series of operating cost accounts from the previous examples but examines them from the point of view of which will change and which will remain constant if a relatively minor service change is being tested. Under this technique, fixed costs are identified, totaled, and set aside from the analytical process to be added back in at the end.

Variable accounts are addressed in one of two ways. Those that are relatively small or whose value is expected to vary in direct proportion to the service change scale are treated in a standard cost allocation fashion as previously described. Fuel costs are an example of this type of account and a simple unit cost/vehicle-mi would be calculated and applied to the proposed service change variance in vehicle-mi. Those variable accounts that are large or whose value varies disproportionately with a service change are given special analysis. Driver wages and benefits, for instance, are affected not only by the service change scale, but also by the characteristics of the change. For example, service added (or subtracted) during peak periods will have different impacts than service changes during other times of the day.

Table 9-8 is an example result of allocating costs to the categories previously mentioned. The transit system used for this example is an all-bus operation. The 51% of total cost to be "estimated by special analysis" comes from two accounts: operators' salaries and wages and operators' fringe benefits. The 29% allocated on a vehicle-mi basis comprises fuel and lubricants, tires and tubes, vehicle servicing, vehicle inspection and maintenance, accident repairs, and claims. The 4% allocated on a vehicle-h basis includes vehicle movement control and ticketing and fare collection. The 16% fixed costs include primarily administrative services such as personnel, data processing, and marketing. It also includes maintenance of fixed facilities such as garages, offices, and passenger stations/shelters.

TABLE 9-7
Operating-Cost-Allocation-Model Results —Bus Operators

Unit Cost Factors

Carrier	Ownership	Vehicle-Hours (\$/vehicle-h)	Vehicle-Miles (\$/vehicle-mi)	Peak Vehicle Needs (\$/peak-vehicle)	System Revenue (\$/\$)
Urban/suburban ^b					
Chicago Transit Authority (CTA)	Public	11.13	0.2	20,059	0.06
South Suburban Safeways (SSS)	Private	6.21	0.18	11,174	0.11
Suburban Transit System (STS)	Private	4.44	0.21	7645	0.07
United Motor Coach (UMC)	Private	5.08	0.21	5681	0.08
West Towns (WT)	Private	8.31	0.17	6533	0.07
Suburban/local ^C					
Aurora Transit Systems (ATS)	Public	6.03	0.11	13,831	0.11
Elgin Department of Transportation (ELG)	Public	4.54	0.18	5964	0.07
Joliet Mass Transit District (JMID)	Public	4.49	0.11	3161	0.12
Waukegan North Chicago (WNC)	Private	5.17	0.11	4164	0.06
Village of Wilmette (WIL)	Public	5.23	0.26	5358	0.21

aMetric conversion: 1 mi = 1.6 km. bProvides service between downtown Chicago and nearby suburban communities. CProvides service within outlying satellite communities.

Source: Adapted from Walter Cherwony and Brian McCollom, "Development of Multi-Modal Cost Allocation Models," in *The Proceedings of the Fourth Intersociety Conference on Transportation* (Los Angeles: The American Society of Mechanical Engineers, July 1976), pp. 1-9.

TABLE 9-8
Operating Cost by Major Category

	Dollar Amount	Percentage of Total Operating Coasts	Percentage of Variable Operating Costs
Variable costs			
Estimated by Special analysis	\$32,946,460	51%	61%
Estimated by Cost allocatio			
Miles	\$19,179,677	29%	35%
Hours	<u>2,419,229</u>	<u>4%</u>	<u>5%</u>
<u>Subtotal</u>	\$21,598,906	33%	40%
Total variable	\$54,545,366	84%	100%
Fixed costs	<u>\$10,636,972</u>	<u>16%</u>	<u>-</u>
Total operating costs	\$65,182,338	100%	-

Source: Booz, Allen & Hamilton, *Bus Route Costing Procedures Interim Report No. 2: Proposed Method*, prepared for UMTA, Report no. UMTA-IT-09-9014-81-1 (Washington, D.C.: Urban Mass Transportation Administration, May 1981), Exhibit 3-2, following p. 8.

The complex part of dealing with incremental costing is developing methods to handle the driver costs "estimated by special analysis." There are 14 identified models (and perhaps as many again that have not been identified) to deal with driver costs. All have advantages and disadvantages, and their analysis and critique could fill a book by itself. For purposes of illustration, one of these models is described here.

The London Transport model requires pay-hour data stratified by shift type. These data are obtained from a sample of driver assignments. The model also requires a definition of the daily vehicle-hours and number of vehicles by time period required to operate the service under consideration.

263

264 Comparing Alternatives

Algorithm. The model's algorithm relates driver cost to the number of straight and split shifts through Eq. (9-13):

$$DL = L1s1 + L2s2 \quad (9-13)$$

where *DL* = total driver pay-hours under the London Transport model

L1 = average hours paid per split shift

L2 = average hours paid per straight shift

s1 = number of split shifts

s2 = number of straight shifts

The coefficients *L1* and *L2* are found from a sample of existing driver schedules stratified by shift type and hours paid. The coefficient values are the sample averages obtained by dividing the total hours worked for a particular shift type by the number of shifts of that type.

Though this example utilizes split and straight shifts, alternate categories of work (for example, overtime) can be used as needed to conform with the particular driver assignment practices existing at the application property.

An estimate of the number of split and straight shifts is needed as input to the model to estimate the cost of a proposed service change. The London Transport model contains a procedure for estimating straight and split shifts, unlike most other costing techniques, which do not address the resource requirements estimation task. The shift estimating procedure is illustrated in Table 9-9.

TABLE 9-9
London Transport Model
Example Driver Cost Calculation

Shift Calculation				
(1)	Vehicle-hours =			= 182
(2)	Total shifts =	182	- 6.67 (veh.-h/shift)	= 27
(3)	Peak ends =	18 morning	+ 19 evening	= 37
(4)	Straight Shifts =	2(27)	- 37	= 17
(5)	Split shifts =	27	- 17	= 10
Cost Calculation				
		Straight Shifts	Split Shifts	Total
(6)	Shifts required	17	10	27
(7)	Average pay-hours per shift type	8.0	11.5	—
(8)	Driver pay-hours required	136	115	251
(9)	Wage rate per pay-hour	\$ 2.00	\$2.00	\$2.00

where PE = number of peak ends
ST = number of straight shifts
SP = number of split shifts
T = total shift requirements

Solving this pair of simultaneous equations gives

$$ST = S(T) - PE \quad (9-15)$$

Thus, the number of straight shifts can be found from the know number of peak ends and total shifts. As shown in line 4, the example requires 17 straight shifts. A balance of 10 split shifts (line 5) is required to achieve the total shift requirements of 27.

265

266 Comparing Alternatives

Once calculated, the shift requirements are multiplied by the coefficient values previously obtained from the sample to produce driver pay-hours required. Driver cost is the product of this pay-hour quantity and the wage rate.

Output

follows.

Automatic train operation (ATO). The rapid transit system will be fully automatically controlled from a central tower. It is estimated that ATO will require an average of 10 operators per shift, on a three shift per day basis. One spare shift will be required to cover holidays, vacations, sickness, and so on, producing a total staff requirement of 40 operators. At peak periods, the 10 console operators would be distributed as follows: 4 train controllers, 4 station surveillance, and 2 power controllers. This operator requirement would be reduced in off-peak periods.

Station operation. Station operations will be automated to the extent possible. Ticket vending machines, automatic turnstiles, and bill changers will be available at each station. While the reliability of these is being improved by the manufacturers, failures are apt to occur. When such failures occur, it is necessary to (1) operate affected items manually to afford minimum delay to passengers and (2) repair the failed appliance as rapidly as possible. It is estimated that approximately one man per station, or a staff of 50, will be able to oversee operations and perform ticket-collecting functions in the event of failures.

To provide for repair of vending machine failures, service of escalators, structural repairs, lighting replacements, air conditioning, and plant servicing, a staff of 50 maintenance engineers will be required. Again, these will be allocated among appropriate shifts with cover for holidays and so on.

Other station staff will include the security force. Each station will have closed-circuit television surveillance. If vandalism or a disturbance is detected, however, the security force must respond quickly. Road patrols will visit stations on a random roving basis and be in radio communication with the control center at all times. An additional function of the security staff is to empty the cash from the vending and change machines. It is estimated that a security staff of 50 will be required.

Two categories of maintenance engineers will be concerned with guideway maintenance—the track and power crew and the ways crew. The track and power crew will maintain the running surface, the power system, the communications system, and the trackside units of the control system. The ways crew will maintain and repair the track structure, including support columns.

Other operating costs. Other operating costs will be incurred in the form of replacement parts for vehicles and structures, power purchased, and general accident and other insurance for the system.

The cost of electric power for the entire system, including traction, lighting, heating, console operations, and communication, is estimated at 30 cents/vehicle-mile/year. Annual mileage of 30 million vehicle-miles produces a total power cost of \$9 million/year.

These estimates result in a buildup of direct salaries of all operating personnel, including allocations for supervisory personnel and employee benefits. These personnel costs, when added to operating expenses for materials, spares, power, and insurance, produce the overall operating expense estimates indicated in Table 9-10.

Depending upon the problem at hand (that is, estimating operating expenses for changes to an existing system versus installation of a totally new system), either of the preceding two techniques can provide reasonable estimates of operating costs for any mode being analyzed. The advantage of the cost allocation model approach is that it permits not only systemwide cost estimates but also operating expense estimates for individual elements of a system, such as a bus route or a single line of a rail rapid transit/AGT proposal.

Wages and salaries

Automatic train operation

Console operators	40	35,000	1400
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Station operation

Custodian/ticket collectors	50	28,000	1400
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Appliance maintenance	25	35,000	875
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General maintenance	25	35,000	875
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Security force	50	30,000	1500
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Cleaners	50	20,000	1000
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Vehicle maintenance

Mechanical	80	35,000	2800
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Electrical	40	42,000	1680
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Electronic	25	50,000	1250
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Laborers	30	20,000	600
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Clerical	20	25,000	500
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Yard operations

Hostlers	30	25,000	750
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Cleaners	40	20,000	800
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Roadway maintenance

Track and power crew	20	40,000	800
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Ways crew	20	35,000	<u>700</u>
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\$16,930

Employee benefits, pension, etc. (35%)	5,930
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Administration/supervision (25%)	<u>4,230</u>
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Total	\$27,090
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Maintenance materials and spares

Station materials 48 @ \$35,000/station

1,680

Roadway materials 45 @ \$70,000/mi

3,150

Vehicle materials 380 @ \$9000/vehicle

3,420

Power 30 million vehicle-mi @ \$0.30

9,000

Insurance

2,000

Estimated annual costs

\$46,340

Contingency (10%)

4,630

CAPITAL COSTS

Capital costs of transit systems vary significantly and are influenced by design standards, type of equipment, quantity of purchase, local conditions of climate and terrain, and other factors. Bus system capital expenses essentially comprise vehicles and maintenance facilities. Related street furniture, such as shelters and informational signs, are a relatively minor part of the total. Rail transit capital costs contain two of the same elements as bus costs (that is, vehicles and maintenance facilities), but also include guideway, track, stations, power, signals and communications, and other capital expenses.

Unlike the operating expense example, there is no formula approach to capital cost. Each component of a planned new system or for renovation of an existing system should be subjected to a careful engineering analysis that flows from the functional characteristics of the proposed system and estimates of demand for that system. For example, the typical planning process produces modal split data assigning trips to a projected alternative. These trips, in turn, determine the number of vehicles required on the system, the optimum spacing of stations, fixed-facility type, and other elements. While gross unit statistics can be used for very preliminary estimates of the magnitude of expenditure, decisions on implementation of a system require careful engineering analysis.

As this engineering analysis proceeds, typically alternative systems will be examined so that the planned improvement, expansion, or new system construction can be assessed in light of cost effectiveness and other criteria. This analysis is performed by postulating modal options for a given corridor, costing those options, comparing that to the resultant demand and other impacts on the community, and combining all statistics in a cost—benefit or other type of comparative analysis to decide on the appropriate mode.

The variance in capital cost precludes simple unit cost comparisons. For example, recent heavy rail projects in Washington, D.C., Atlanta, Baltimore, and Miami have varied from \$60 million to \$170 million/rte.-mi. Light rail systems built in Buffalo, Pittsburgh, Portland (Oregon), and Sacramento (California) have ranged from \$10 million to \$110 million/rte.-mi.

Vehicle costs also vary depending on type, specification, and other amenities. Rail cars vary from \$1,100,000 to \$1,800,000 each. Buses are in the \$200,000 range. To truly judge the total cost of different systems, obviously operating expense must be added and both sets of cost placed on an annual expenditure basis by amortizing capital costs. Furthermore, comparative analysis should examine the present worth of future total investment (capital and operating) by, in effect, "capitalizing future operating expenses." In this way, through the use of operating-cost-allocation models and capital-cost engineering estimates, a complete cost analysis can be prepared for utilization in an alternatives analysis to select the appropriate transit mode.

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FURTHER READING

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270

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EXERCISES

9-1 What is the single biggest factor to examine in reducing operating cost?

9-2 You have completed a fully allocated cost model for your system and the results indicate: Cost = (\$0.91 x vehicle-miles) + (\$22.80 x vehicle-hours) + (\$71,400 x peak vehicles). What is the cost of Route 18, which

line, assuming the maintenance facility constructed for the first line has the capacity to handle the new vehicles. Also, comment on why you did not use other methods.

9-6 Using the unit cost data from this chapter and information from other chapters, discuss whether or not there appear to be economies of scale in transit operations.